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DIODE

STEP STRESS TESTING PROGRAM

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FINAL REPORT
FOR

JANTX 1N2970B

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Prepared
For

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FOREWORD

This report is a summary of the work performed on NASA Contract NAS8-31944. The investigation was conducted for the National Aeronautics and Space Administration, George C. Marshall Space Flight Center, Huntsville, Alabama. The Contracting Officer's Technical Representative was Mr. F. Villella.

The short-term objective of this preliminary study of transisters, diodes, and FETS is to evaluate the reliability of these discrete devices, from different manufacturers, when subjected to power and temperature step stress tests.

The long-term objective is to gain more knowledge of accelerated stress testing for use in future testing of discrete devices, as well as to determine which type of stress should be applied to a particular device or design.

This report is divided as follows: description of tests, figures, tables, and appendix.

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1.0 INTRODUCTION

DCA Reliability Laboratory, under Contract NAS8-31944 for NASA/Marshall Space Flight Center, has compiled data for the purpose of evaluating the effect of power/temperature step stress when applied to a variety of semiconductor devices. This report covers the zener diode JANTX1N2970B manufactured by Siemens and General Semiconductor, Inc.

A total of 48 samples from each manufacturer was submitted to the process outlined in Table 1. In addition, two control sample units were maintained for verification of the electrical parametric testing.

2.0 TEST REQUIREMENTS

2.1 Electrical

All test samples were subjected to the electrical tests outlined in Table 2 after completing the prior power/temperature step stress point. These tests were performed using the Fairchild Model 600 High-Speed Computer-Controlled Tester. Additional bench testing was also required on the devices.

2.2 Stress Circuit

The test circuit shown in Figure 1 was used to power all the test devices during the power/temperature stress conditions. The voltage was set by V_Z and the current was varied in order to comply with the specified power rating for the device. At least one of the devices was subjected to maximum rated power (MRP). All remaining devices were

subjected to no less than 90% of MRP. See Figure 1 for load resistance values and voltages.

2.3 Group I - Power Stress

Thirty-two units, 16 from each manufacturer, were submitted to the Power Stress Process. The diodes were stressed in 500-hour steps at 50, 100, 125, 150 and 175 percent of maximum rated power (MRP) for 2500 hours or until 50% or more of the devices in a sample lot failed.* Electrical measurements were performed on all specified electrical parameters after each power step. See Table 1. (*See Notes at end of text.)

2.4 Group II - Temperature Stress I

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress I Process. Group II was subjected to 1600 hours of stress at maximum rated power in increments of 160 hours. The temperature was increased in steps of 25°C, commencing at 75°C and terminating at 300°C or until 50% or more of the devices failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

2.5 Group III - Temperature Stress II

Thirty-two units, 16 from each manufacturer, were submitted to the Temperature Stress II Process. Group III was subjected to 112 hours of stress at maximum rated power in increments of 16 hours. The temperature was increased in steps of 25°C, commencing at 150°C and terminating at 300°C or until 50% or more of the devices in a sample lot

failed.* Electrical measurements were performed on all specified electrical parameters after each temperature step. See Table 1.

3.0 DISCUSSION OF TEST RESULTS

3.1 Group I - Power Stress

3.1.1 General Semiconductor. The General Semiconductor (GSI) sample lot completed 1750 hours of Group I Testing before the lot was stopped because more than 50% of the devices failed. The first seven failures occurred 150 hours into the 150% MRP step. Serial numbers 9417, 9428, 9430, 9437, 9438, 9439 and 9440 failed the maximum ^{B}V limit. The last five failures occurred 250 hours into the 150% MRP step. Serial numbers 9431, 9432, 9433, 9434 and 9435 failed the minimum ^{B}V limit. Typical characteristics of this sample lot's performance were:

1) The mean value for ^{I}R changed 1.80μA from an initial mean of 69.70μA to a final mean of 71.50μA.
2) The mean value for ^{B}V changed .259V from an initial mean of 6.983V to a final mean of 7.242V.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.2 Siemens. The Siemens sample lot completed 1650 hours of Group I Testing before the lot was stopped because more than 50% of the devices failed. The first failure occurred 25 hours into the 125% MRP step. Serial number 9493 failed the

maximum I_R limit. The next failure occurred 250 hours into the 125% MRP step. Serial number 9481 failed the maximum I_R limit. The next failure occurred 10 hours into the 150% MRP step. Serial number 9489 failed the maximum I_R limit. The next failure occurred 25 hours into the 150% MRP step. Serial number 9486 failed the maximum I_R limit. The next failure occurred 50 hours into the 150% MRP step. Serial number 9496 failed the maximum I_R limit. The last five failures occurred 150 hours into the 150% MRP step. Serial numbers 9483, 9488, 9487 and 9495 failed the maximum B_V limit. Serial number 9491 failed the maximum I_R limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 728.2nA from an initial mean of 636.8nA to a final mean of 1.365μA.
2) The mean value for B_V changed .174V from an initial mean of 6.902V to a final mean of 7.076V.

The control units for this sample lot remained constant throughout the entire Group I Testing.

3.1.3 Statistical Summary - Group I. Table 4 outlines the results of Group I - Power Stress Process for each of the electrical parameters and all measurement points for both General Semiconductor and Siemens.

3.2 Group II - Temperature Stress I

3.2.1 General Semiconductor. The General Semiconductor sample lot completed 800 hours of Group II Testing

before the lot was stopped because more than 50% of the devices failed. The first five failures occurred 160 hours into the 150°C-temperature step. Serial number 9454 was removed from the Group II Testing as a visual catastrophic failure. (See Table 8.) The last five failures occurred 160 hours into the 175°C-temperature step. Serial numbers 9443, 9451, 9453, 9456 and 9457 were removed from the Group II Testing as visual catastrophic failures. (See Table 8.) Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 30.74μA from an initial mean of 64.31μA to a final mean of 95.05μA.
2) The mean value for B_V changed .085V from an initial mean of 6.956V to a final mean of 7.041V.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.2 Siemens. The Siemens sample lot completed 480 hours of Group II Testing before the lot was stopped because more than 50% of the devices failed. The first failure occurred 160 hours into the 75°C-temperature step. Serial number 9501 was removed from the Group II Testing as a visual catastrophic failure. (See Table 8.) The last nine failures occurred 160 hours into the 125°C-temperature step. Serial numbers 9498, 9500, 9502, 9504, 9506, 9508, 9510, 9511 and 9512 were removed from the Group II Testing as visual catastrophic failures. (See Table 8.) Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 1.73μA from an initial mean of 4.68μA to a final mean of 2.95μA.

2) The mean value for ^{B}V changed .109V from an initial mean of 6.956V to a final mean of 7.065V.

The control units for this sample lot remained constant throughout the entire Group II Testing.

3.2.3 Statistical Summary - Group II. Table 5 of this report outlines the results of Group II - Temperature Stress I Testing, for each of the electrical parameters and all of the measurement points pertaining to both General Semiconductor and Siemens.

3.3 Group III - Temperature Stress II

3.3.1 General Semiconductor. The General Semiconductor sample lot completed the entire 112 hours of Group III Testing with one catastrophic failures. The failure occurred 16 hours into the 300°C-temperature step. Serial number 9461 failed the maximum I_R limit. Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 620.54μA from an initial mean of 63.66μA to a final mean of 684.2μA.

2) The mean value for ^{B}V changed .105V from an initial mean of 6.920V to a final mean of 6.815V.

The control units for this sample lot remained constant throughout the entire Group III Testing.

3.3.2 Siemens. The Siemens sample lot completed 96 hours of Group III Testing before the lot was stopped because more than 50% of the devices failed. The first two failures occurred 16 hours into the 225°C-temperature step. Serial numbers 9517 and 9528 failed the maximum I_R limit. The next five failures occurred 16 hours into the 250°C-temperature step. Serial numbers 9513, 9524 and 9525 failed the maximum ^BV limit. Serial numbers 9516 and 9526 failed the maximum I_R limit. The last eight failures occurred 16 hours into the 275°C-temperature step. Serial numbers 9514, 9518 and 9519 failed the maximum ^BV limit. Serial numbers 9520, 9521, 9522, 9523 and 9527 were removed from the Group III Testing as visual catastrophic failures. (See Table 8.) Typical characteristics of this sample lot's performance were:

1) The mean value for I_R changed 1.689mA from an initial mean of 2.406μA to a final mean of 1.691mA.
2) The mean value for ^BV changed .868V from an initial mean of 6.701V to a final mean of 7.569V.

The control units for this sample lot remained constant throughout the entire Group III Testing.

3.3.3 Statistical Summary - Group III. Table 6 outlines the results of Group III - Temperature Stress II Testing, for each of the electrical parameters and all of the measurement points for both General Semiconductor and Siemens.

4.0 FINAL DATA SUMMARY

Table 7 statistically summarizes the change in the mean value from the zero-hour data to the final data. The graphs of Figures 2 and 4 plot the cumulative percent failures versus the temperature stress level for Group II - Temperature Stress I, and Group III - Temperature Stress II. The graphs of Figures 3 and 5 plot the time step for Group II (160 hours) and Group III (16 hours) versus the temperatures T_1 and T_2 calculated from Figures 2 and 4. Tables 8 and 9 summarize the failures encountered for all three stress groups. The failures are separated into two categories: catastrophic failures in Table 8 and parametric failures in Table 9. The data from Table 8 were used as a source for the graphs in Figures 2 and 4. Figures 2 and 4 were used as a source for the graphs in Figures 3 and 5, respectively. Junction temperature is plotted on an inverse hyperbolic scale.

5.0 CONCLUSIONS

The testing proved strenuous for both General Semiconductor (GSI) and Siemens. In Groups I and II Testing, both manufacturers were stopped. although GSI underwent more hours of testing in each case.

In Group II the predominant failure mode was detachment of the cathode lead. Failure analysis revealed that all analyzed samples failed due to the effects of excess heat. The separation of the tubulations was caused by extreme heat acting upon

the glass and the metal tube. While the dice of the GSI devices have been destroyed by alloying with the metal connecting metal, the Siemens dice are still functional and are within end point limits when tested by external probing of the die-lidded samples. Possibly this difference between manufacturers is due to deeper junctions on the Siemens parts.

Since GSI had only one failure under Group III Testing, only the Siemens lot underwent failure analysis. The analyzed samples were subjected to heat and power beyond their stress limits, which caused destructive damage to their internal structures. The protective junction coating has been charred, leading to excess leakage. The die and internal lead attach metal has been melted and the "second nickel" plate used on the dice has peeled and separated with the connecting bonding metal. In addition, all the dice are shorted (probably due to "thermal runaway") and two of the devices have cracks or chip-outs. The die fell out of one device when it was touched. In summary, the samples failed due to excessive thermal and electrical stress.

A plot showing the cumulative failure distribution for Group III was drawn for the Siemens sample lots (Figures 4 and 5), but because of the visual catastrophic failures Group II could not be drawn nor could the GSI sample lot be completely plotted (Figures 2 and 3). For these same reasons, neither lot could have its activation energy calculated.

A broken circle around a marked point on the graph indicates a freak failure not calculated as part of the regression line. A solid circle around a marked point indicates an isolated mean failure point. The regression line was calculated using the least squares method.

The activation energy was calculated from the formula:

$$E = \left[\ell n \left(\frac{t_1}{t_2}\right)\right]\left[\frac{8.63 \times 10^{-5}\ eV/^{o}K}{\left(\frac{1}{T_1+273}\right) - \left(\frac{1}{T_2+273}\right)}\right] eV$$

Where: t_1 = step of Group II - Temp Stress I = 160 hrs.

t_2 = step of Group III - Temp Stress II = 16 hrs.

T_1 = temperature in ^{o}C of 16% failure for Group II.

T_2 = temperature in ^{o}C of 16% failure for Group III.

NOTE:

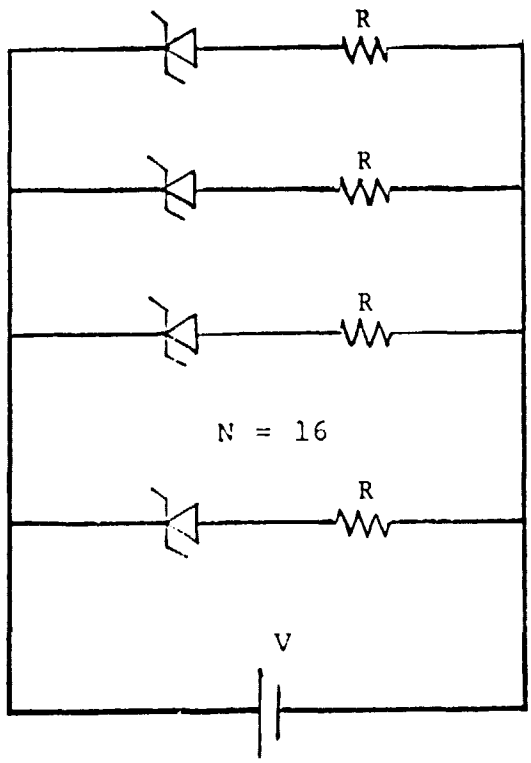
* Conditions for failure:

A) Open or short

B) Leakage exceeds the maximum limit by 100 times

C) Other parameters exceed MIL limits by 50% or more.

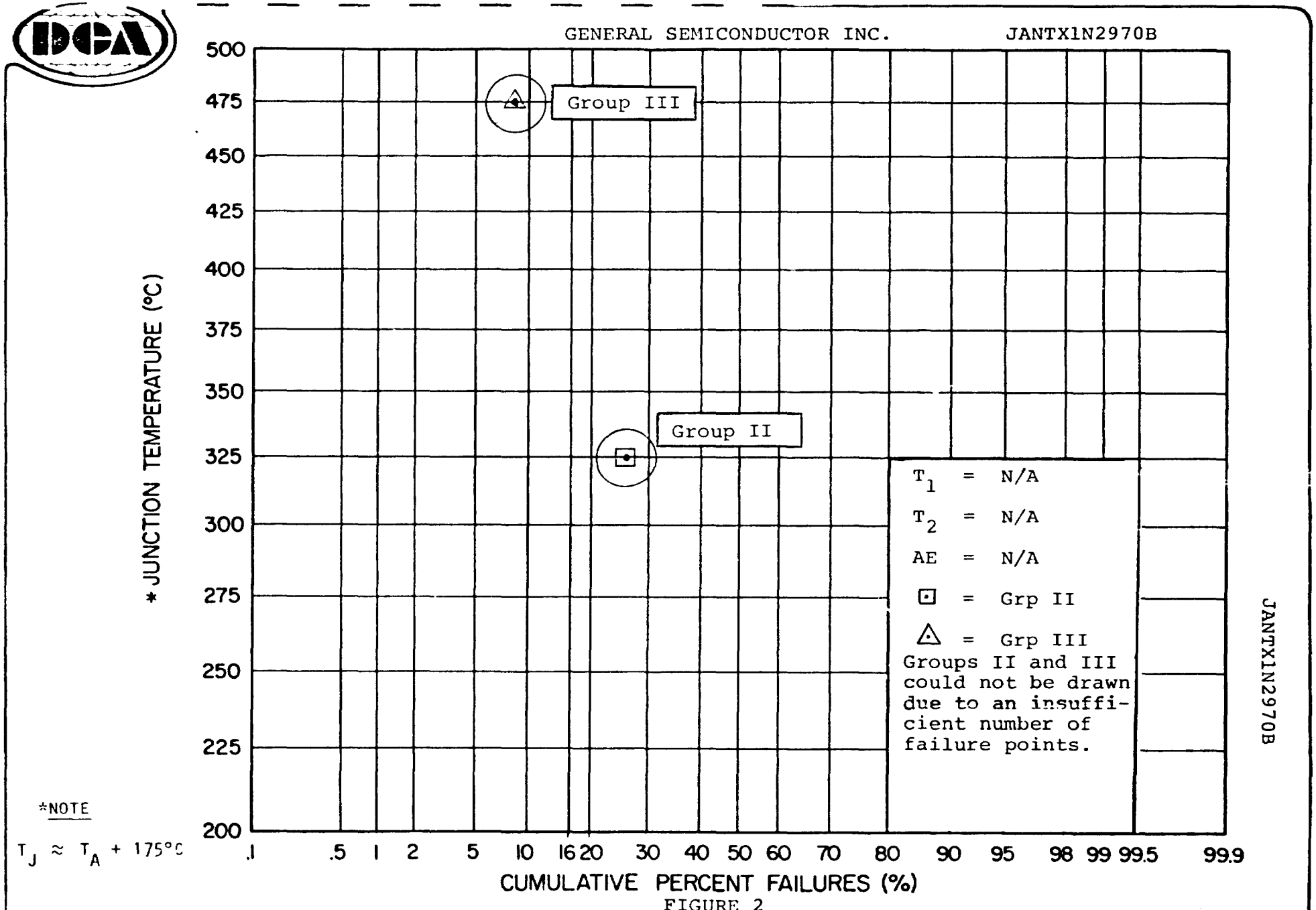
ZENER DIODES



$R = VZ \div 1.75\ IZ_{MAX} \pm 50\%$

$P_d = VZ^2 \div R$

FIGURE 1
Power/Stress Circuit for
JANTX1N2970B



*NOTE

$T_J \approx T_A + 175°C$

FIGURE 2

Cumulative Percent Failures Versus Junction Temperature, General Semiconductor

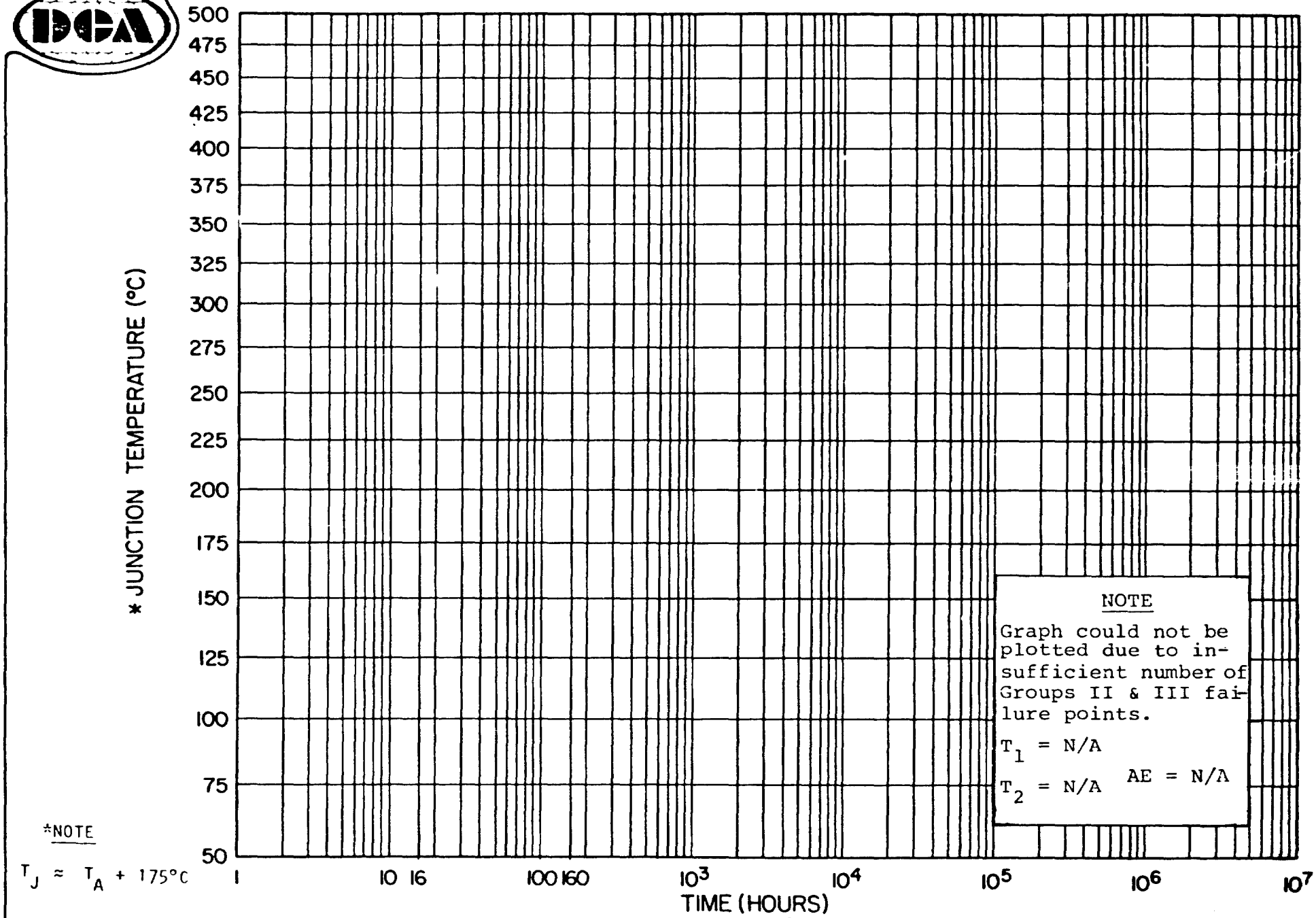
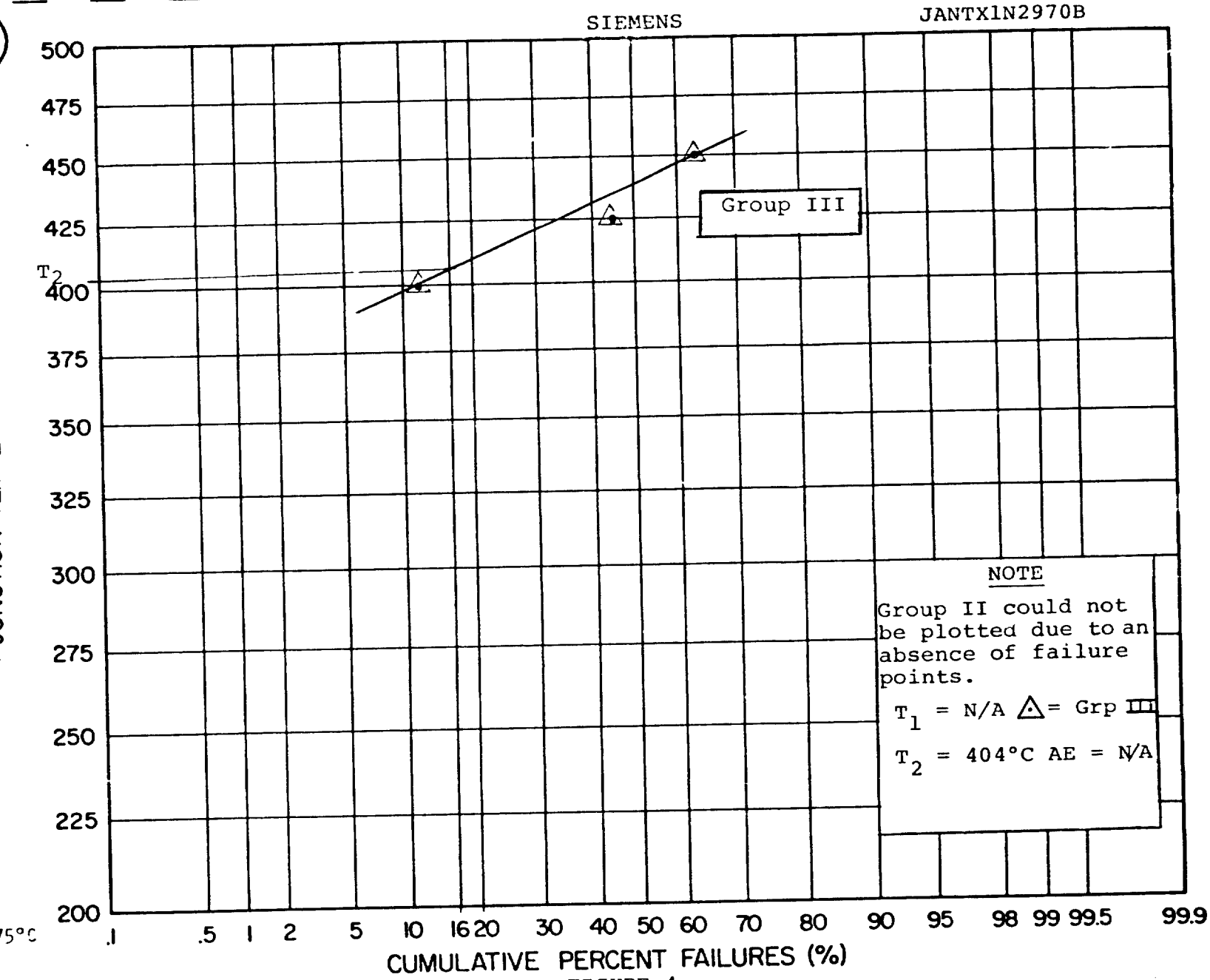


FIGURE 3
Time Steps Versus Junction Temperature, General Semiconductor

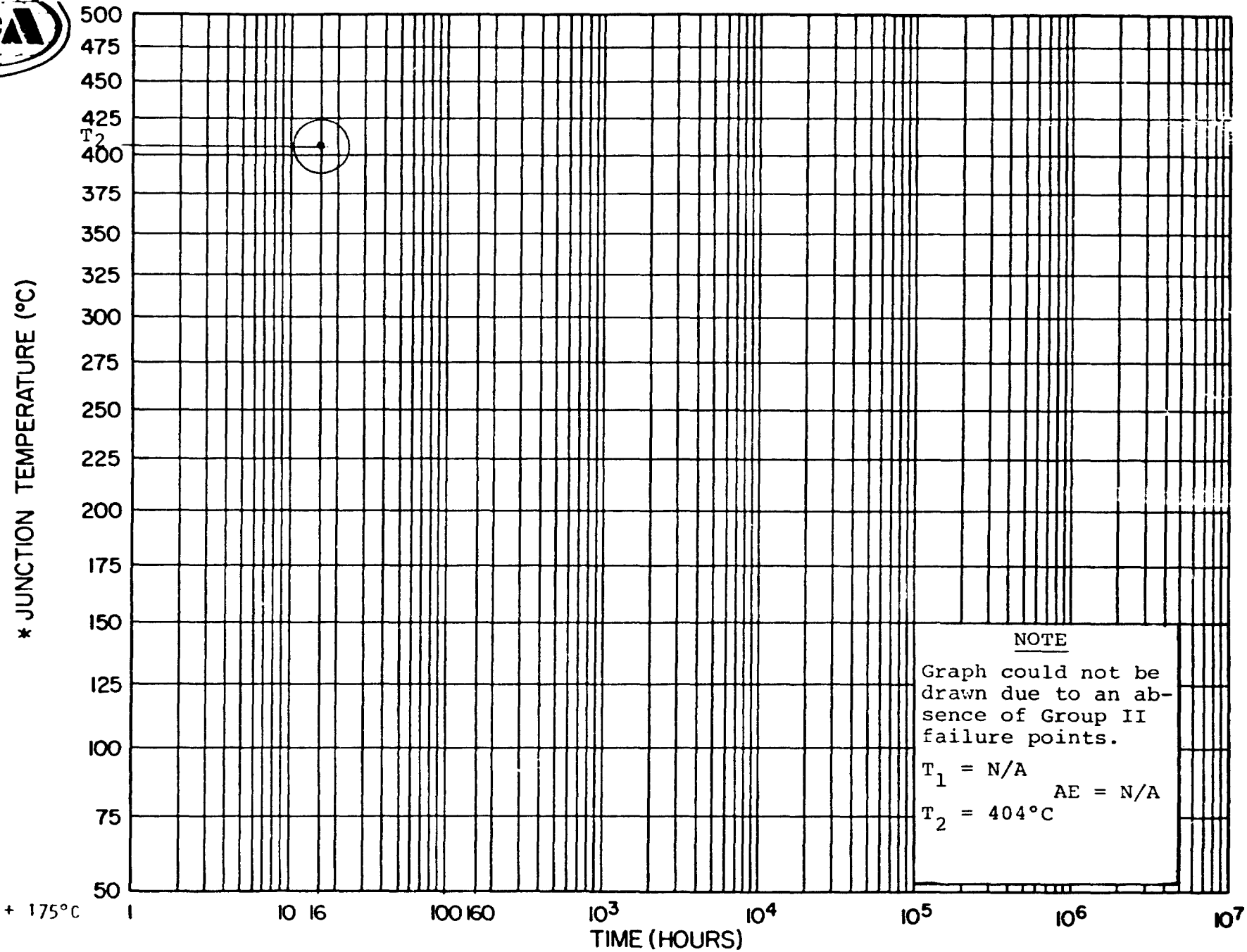


*NOTE

$T_J \approx T_A + 175°C$

FIGURE 4

Cumulative Percent Failures Versus Junction Temperature, Siemens



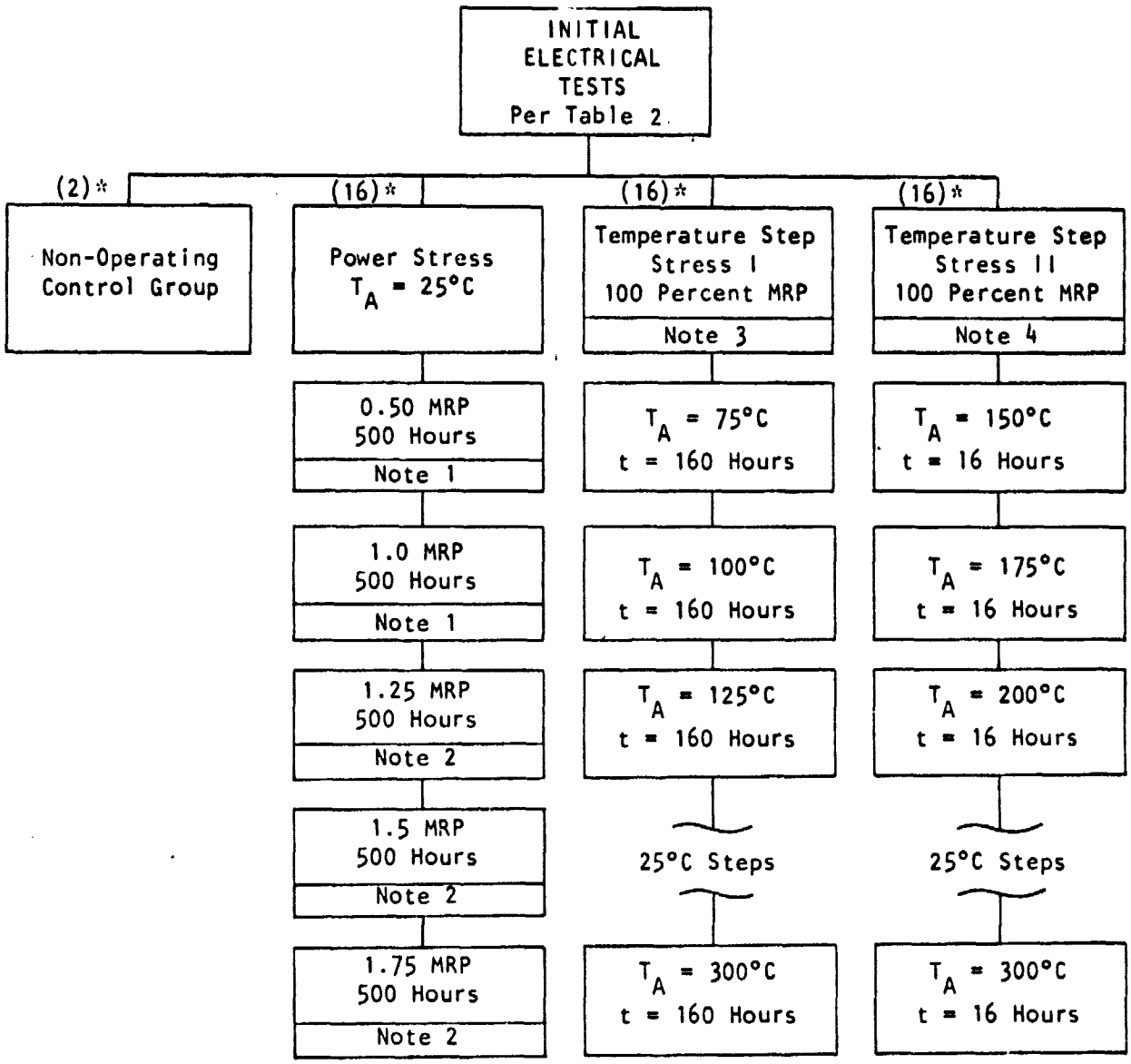
*NOTE

$T_J \approx T_A + 175°C$

FIGURE 5

Time Steps Versus Junction Temperature, Siemens

TABLE 1
TEST FLOW DIAGRAM



*Quantity per manufacturer (Siemens and General Semiconductor)

NOTES:

1) Electrical measurements per Table 2 were made at 50, 150, 250 and 500 hours.
2) Electrical measurements per Table 2 were made at 10, 25, 50, 150, 250 and 500 hours.
3) Electrical measurements per Table 2 were made at the end of each 160 hours.
4) Electrical measurements per Table 2 were made at the end of each 16 hours.

TABLE 2
PARAMETERS AND TEST CONDITIONS

PARAMETER	CONDITIONS	SPEC. LIMIT		CAT. LIMIT		UNITS
		MIN	MAX	MIN	MAX	
I_R	@ V_R = 5.2V		.15		15	mA
B_V	@ I_Z = 370mA	6.46	7.14	3.23V	10.71	V

NOTES:
1/ In addition, any open or short shall be considered catastrophic

TABLE 3
POWER STRESS BURN-IN CONDITIONS

V_Z = 6.8V	
I_Z =	Percent P_D
367.0mA	50
735.0mA	100
919.0mA	125
1102.0mA	150
1286.0mA	175

NOTE
FOR TABLES
4 THROUGH 7

The minimum/maximum initial and final data generally have an absolute accuracy of ±1% of the reading and ± one digit except for readings greater than 9.99mA which have an absolute accuracy of ±2% of the reading and ± one digit. The data also have a resolution for four digits. The standard deviations, means, delta means, and average means are, therefore, valid indicators of trends over time and temperature, excepting the minor statistical computer error of supplying a constant number of significant digits.

TABLE 4
GROUP I – POWER STRESS DATA SUMMARY

PARAMETER	I_R = 150μA(MAX)		B_V=6.46V(MIN) 7.14(MAX)					
CONDITIONS AND LIMIT	V_R = 5.2V		I_Z = 370.0mA					
IDENTIFICATION	GSI	SIE	GSI	SIE				
INITIAL DATA								
MIN VALUE	48.6μA	.0326μA	6.879V	6.540V				
MAX VALUE	120.0μA	3.890μA	7.065V	7.123V				
MEAN	69.70μA	.6368μA	6.983V	6.902V				
STD DEV	63.3μA	.8816μA	.04649V	.1802V				
INTERIM DATA								
POWER 50 TO 125% Δ MEAN VALUE								
50% POWER								
50 HRS	5.78μA	.0269μA	-.001V	-.003V				
150 HRS	10.72μA	.0637μA	.007V	.011V				
250 HRS	17.23μA	.3772μA	.001V	.005V				
500 HRS	24.48μA	.0839μA	.004V	.007V				
100% POWER								
550 HRS	26.02μA	.0808μA	0.00V	.005V				
650 HRS	30.06μA	.1088μA	-.007V	.008V				
750 HRS	34.80μA	.0873μA	.002V	.014V				
1000 HRS	41.40μA	.1472μA	.005V	.020V				
125% POWER								
1010 HRS	41.5μA	.1568μA	.014V	.037V				
1025 HRS	40.4μA	.1491μA	.019V	-0.000V				
1050 HRS	40.8μA	.1387μA	.034V	.070V				
1150 HRS	41.4μA	.3306μA	.045V	.069V				
1250 HRS	47.2μA	.1481μA	.019V	.035V				
1500 HRS	54.9μA	.3722μA	.038V	.050V				

(continued on second sheet)

TABLE 4 (Cont'd)

(continued from first sheet) GROUP I — POWER STRESS DATA SUMMARY

PARAMETER	I_R = 150µA		B_V=6.46V(MIN) 7.14V(MAX)					
CONDITIONS AND LIMITS	V_R = 5.2V		I_Z = 370mA					
IDENTIFICATION	GSI	SIE	GSI	SIE				
INITIAL DATA								
MIN VALUE	48.6µA	.0326µA	6.879V	6.540V				
MAX VALUE	120.0µA	3.890µA	7.065V	7.123V				
MEAN	69.70µA	.6368µA	6.983V	6.902V				
STD DEV	63.3µA	.8816µA	.04649V	.1802V				
INTERIM DATA								
POWER 150 TO 175% Δ MEAN VALUE								
150% POWER								
1510 HRS	48.8µA	.2998µA	.030V	.089V				
1525 HRS	47.3µA	.1329µA	.016V	-.135V				
1550 HRS	49.4µA	.4882µA	.023V	-.346V				
1650 HRS	9.31µA	.7282µA	.016V	.174V				
1750 HRS	1.80µA	JOB STOPPED	.259V	JOB STOPPED				
2000 HRS	JOB STOPPED		JOB STOPPED					
175% POWER								
2010 HRS	↓	↓	↓	↓				
2025 HRS	↓	↓	↓	↓				
2050 HRS	↓	↓	↓	↓				
2150 HRS	↓	↓	↓	↓				
2250 HRS	↓	↓	↓	↓				
2500 HRS	↓	↓	↓	↓				
FINAL DATA								
MIN VALUE	100.0pA	440pA	6.983V	6.764V				
MAX VALUE	184.6µA	3.970µA	7.800V	7.201V				
MEAN	71.50µA	1.365µA	7.242V	7.076V				
STD DEV	70.09µA	1.436µA	.3254V	.1444V				

*NOTE: Catastrophic reject(s) removed from data after this point

TABLE 5

GROUP II TEMP STRESS I DATA SUMMARY

PARAMETERS	I_R = 150μA(MAX)		B_V=6.46V(MIN) 7.14V(MAX)					
CONDITIONS AND LIMITS	V_R = 5.2V		I_Z = 370mA					
IDENTIFICATION	GSI	SIE	GSI	SIE				
INITIAL DATA								
MIN VALUE	43.40μA	.204μA	6.435V	6.435V				
MAX VALUE	80.50μA	55.02μA	7.048V	7.172V				
MEAN	64.31μA	4.681μA	6.956V	6.956V				
STD DEV	9.699μA	13.15μA	.1442V	.1442V				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS. / TEMP (T_A)								
160 / 75°C	14.80μA	-1.67μA	.065V	-.025V				
320 / 100°C	18.67μA	-1.73μA	.094V	.013V				
480 / 125°C	24.12μA	-i.73μA	.093V	.109V				
640 / 150°C	*2.669mA	JOB STOPPED	.092V	JOB STOPPED				
800 / 175°C	30.74μA		.085V					
960 / 200°C	JOB STOPPED		JOB STOPPED					
1120 / 225°C								
1280 / 250°C								
1440 / 275°C								
1600 / 300°C								
FINAL DATA								
FINAL TEMP (T_A)	175°C	125°C	175°C	125°C				
MIN VALUE	66.20μA	.153μA	6.926V	6.913V				
MAX VALUE	108.00μA	27.60μA	7.128V	7.223V				
MEAN	95.05μA	2.954μA	7.041V	7.065V				
STD DEV	14.45μA	7.045μA	.06332V	.09381V				

* NOTE: Catastrophic reject(s) removed from data after this point

TABLE 6

GROUP III TEMP STRESS II DATA SUMMARY (16 HRS.)

PARAMETERS	I_R = 150μA(MAX)		B_V=6.46V(MIN) 7.14V(MAX)					
CONDITIONS AND LIMITS	V_R = 5.2V		I_Z = 370.0mA					
IDENTIFICATION	GSI	SIE	GSI	SIE				
INITIAL DATA								
MIN VALUE	50.80μA	.121μA	6.822V	6.470V				
MAX VALUE	101.00μA	25.90μA	6.985V	7.010V				
MEAN	63.66μA	2.406μA	6.920V	6.701V				
STD DEV	12.22μA	6.148μA	.04397V	.1857V				
INTERIM DATA (INITIAL TO FINAL)								
Δ MEAN VALUE								
TOTAL HRS. TEMP (T_A)								
16 150°C	1.22μA	.116μA	-0.00V	.003V				
32 175°C	-0.04μA	-.087μA	.029V	.030V				
48 200°C	-0.42μA	19.49μA	.006V	.037V				
64 225°C	94.74μA	*1.257mA	-.003V	-.001V				
80 250°C	-1.68μA	*1.456mA	.073V	*.545V				
96 275°C	621.74μA	*1.689mA	.088V	*.868V				
112 300°C	*620.54μA	JOB STOPPED	-.105V	JOB STOPPED				
FINAL DATA								
FINAL TEMP (T_A)	300°C	[illegible]°C	300°C	275°C				
MIN VALUE	52.80μA	280.0pA	4.230V	6.855V				
MAX VALUE	9.99mA	9.99mA	7.069V	9.226V				
MEAN	684.2μA	1.691mA	6.815V	7.569V				
STD DEV	2.403mA	3.322mA	.670V	.9622V				

*NOTE: Catastrophic reject(s) removed from data after this point

TABLE 7
FINAL DATA SUMMARY

PARAMETER	SPECIFICATIONS LIMIT		UNITS	MEAN INT. DATA	AVERAGE Δ IN MEAN VALUE					
					POWER STRESS		TEMPERATURE STRESS I		TEMPERATURE STRESS II	
	MIN	MAX			GSI	SIE	GSI	SIE	GSI	SIE
I_R		150	μA		+32.279	+.21780	*+551.47	-1.710	*+190.87	*+736.92
B_V	6.46	7.14	V		+.02758	+.00556	+.08580	+.03233	+.01257	*+.2470

* NOTE: Catastrophic reject(s) removed from data after this point

JANTX1N2970B

TABLE 8 STEP STRESS CATASTROPHIC FAILURE SUMMARY JAN TX1N2970B

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
100% 50 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	0	-
250 hr.	0	-	0	-
125% 10 hr.	0	-	0	-
15 hr.	0	-	1	B
25 hr.	0	-	0	-
100 hr.	0	-	0	-
100 hr.	0	-	1	B
250 hr.	0	-	0	-
150% 10 hr.	0	-	1	B
15 hr.	0	-	1	B
25 hr.	0	-	1	B
100 hr.	7	A	4 / 1	A / B
100 hr.	5	A	JOB STOPPED	
250 hr.	JOB STOPPED			
175% 10 hr.				
15 hr.				
25 hr.				
100 hr.				
100 hr.				
250 hr.				

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	-	1	C
100° C	0	-	0	-
125 °C	0	-	9	C
150 °C	4 / 1	B / C	JOB STOPPED	
175 °C	5	C		
200 °C	JOB STOPPED			
225 °C				
250 °C				
275 °C				
300 °C				

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150°C	0	-	0	-
175°C	0	-	0	-
200°C	0	-	0	-
225°C	0	-	1 / 1	B / D
250°C	0	-	3 / 2	A / B
275°C	0	-	2 / 1 / 5	A / E / C
300°C	1	B	JOB STOPPED	

MFR "A" - GENERAL SEMICONDUCTOR, INC.

MFR "B" - SIEMENS

NOTES: A - B_V > 10.71V

B - I_R > 15mA

*C - Visual (other than handling)

D - Shorted (verified by failure analysis)

E - Open (verified by failure analysis)

* Cathode lead detaching from the stress.

TABLE 9 STEP STRESS PARAMETRIC FAILURE SUMMARY JAN TX1N2970B

GROUP I POWER STRESS

TEST STEP	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
50% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	1	B
100% 50 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	1	A	0	–
250 hr.	4	A	0	–
125% 10 hr.	0	–	0	–
15 hr.	0	–	1	B
25 hr.	0	–	1	B
100 hr.	0	–	0	–
100 hr.	0	–	0	–
250 hr.	0	–	0	–
150% 10 hr.	0	–	1	B
15 hr.	0	–	0	–
25 hr.	0	–	0	–
100 hr.	0	–	0	–
100 hr.	1	A	JOB STOPPED	
250 hr.	JOB STOPPED			
175% 10 hr.				
15 hr.				
25 hr.				
100 hr.				
100 hr.				
250 hr.				

GROUP II 160 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
75° C	0	–	2	B
100° C	0	–	1	B
125 °C	0	–	0	–
150 °C	0	–	JOB STOPPED	
175 °C	0	–		
200 °C	JOB STOPPED			
225 °C				
250 °C				
275 °C				
300 °C				

GROUP III 16 HR. TEMP. STEPS

TEST STEP (T_A)	MFR A		MFR B	
	QTY.	NOTE	QTY.	NOTE
150 °C	0	–	0	–
175 °C	0	–	0	–
200 °C	0	–	1	A
225 °C	1	A	0	–
250 °C	0	–	1	A
275 °C	0	–	0	–
300 °C	0	–	JOB STOPPED	

MFR "A" - GENERAL SEMICONDUCTOR, INC.

MFR "B" - SIEMENS

NOTES: A - I_R Maximum limit failure

B - B_V Maximum limit failure

APPENDIX A

FAILURE ANALYSIS

TEMPERATURE STRESS I

FAILURE ANALYSIS

Date 16 November 1978

J/N 2CN242-32B **P/N** 1N2970B **MFR** General Semiconductor

End point limits: 3.23-10.71

End point limit: 15mA Max.

S/N	PIV -volts- @ 370mA	I_R @ 5.2 V.dc	V_F @ _____dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
9453	short*	∞ *		11 (175°C - 800 Hrs. Tot)	Lost anode lead & tubulation.
9454	short*	∞ *		09 (150°C- 640 Hrs. Tot)	Broken anode lead & seal.
9456	short*	∞ *		11 (175°C- 800 Hrs. Tot)	Broken G/M seal; open anode lead.
		*Internal probe measurements.		External lead missing.	

VISUAL INSPECTION

The tubulation and internal lead have fallen out of the glass seal on all three GSI samples. On S/N 9453 the die and its mounting disc have also come loose (see Figures A-1 and A-2).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

FAILURE ANALYSIS
(TEMPERATURE STRESS I)

Date 16 November 1978

J/N 2CN242-32B **P/N** 1N2970B **MFR** Siemens

End point Limits: 3.23-10.71

End point Limit: 15mA Max.

S/N	PIV -volts- @ 370mA	I_R @ 5.2 V.dc	V_F @ ____ dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
9501	7.2(R) *	2.04μA *		03 (75°C - 160 Hrs. Tot)	Broken G/M seal.
9506	7.6 *	0.5μA *		07 (125°C- 480 Hrs. Tot)	Lost anode lead
0510	6.8 *	1.0μA *		07 (125°C- 480 Hrs. Tot)	Lost anode lead
	* External lead missing or open. Readings are internal probe measurements.				

VISUAL INSPECTION

The tubulation has broken loose and internal wire lead has broken off on all three Siemens samples (see Figures A-3 and A-4).

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

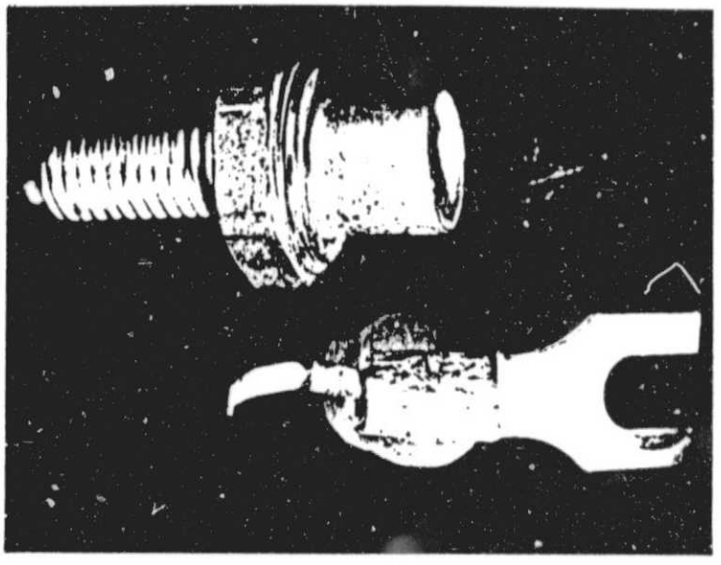


FIGURE A-1
S/N 9454, Typical Visual Defect of GSI Device, 3.3X.
Tubulation and internal lead wire have broken loose.

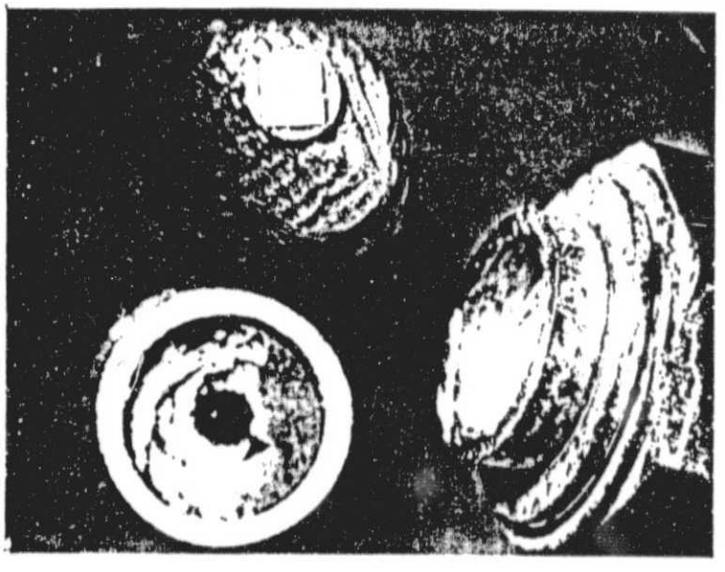


FIGURE A-2
S/N 9453, GSI Sample, 5X.
The tubulation and internal lead are missing;
die and its mounting disc are loose.

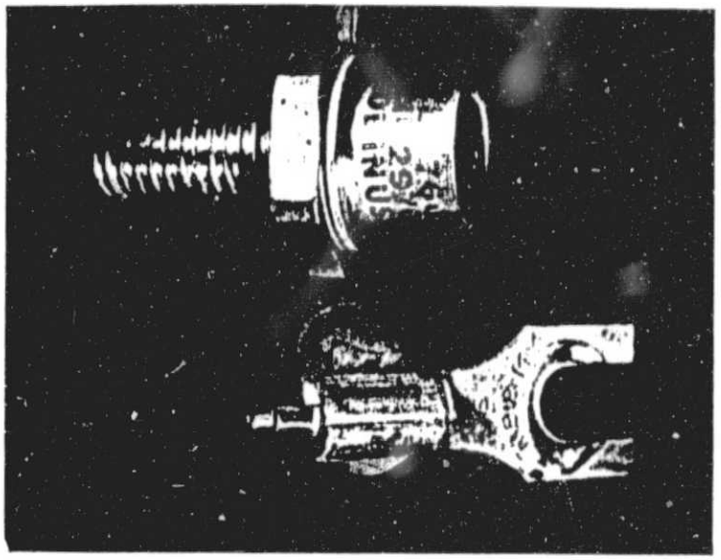


FIGURE A-3
S/N 9506, Typical Visual Defect of Siemens Device, 3.3X.
The tubulation and internal lead
wire have broken loose.

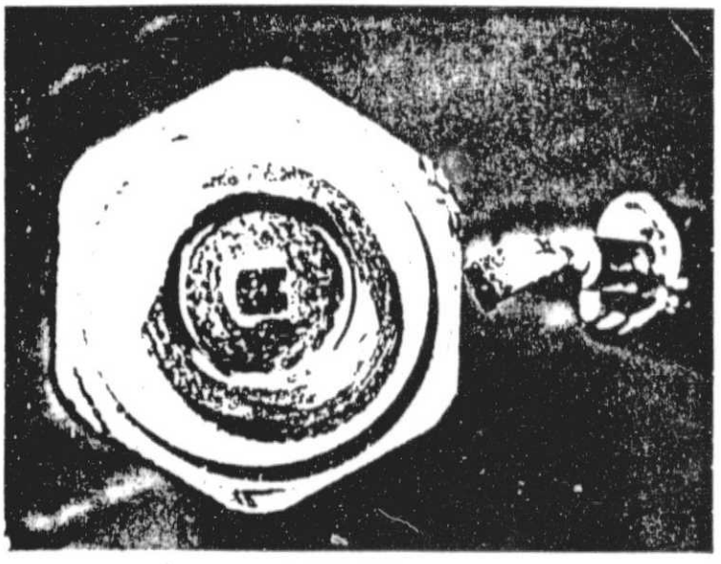


FIGURE A-4
S/N 9501, Siemens Sample, 5X.
The silicon die has split with one-half remaining on the
stud and one-half on the internal contact wire.

CONCLUSIONS

All these General Semiconductor and Siemens samples have failed due to the effects of excess heat. The separation of the tubulations is caused by extreme heat acting upon the glass and the metal tube. While the dice of the GSI devices have been destroyed by alloying with the melted metal, the Siemens dice are still functional and within end point limits when tested by internal probing of the de-lidded samples. Possibly this difference between vendors is due to deeper junctions on the Siemens parts.

APPENDIX B

FAILURE ANALYSIS

TEMPERATURE STRESS II

FAILURE ANALYSIS

Date 8 May 1978

J/N 2CN242-32C P/N 1N2970 MFR Siemens

Max = 150μA Lim=6.46/7.14

S/N	PIV -volts-	I_R @ 5.2V.dc	V_R @ 370mA dc	INITIAL REJ. AT TEST SEQUENCE NO.:	INITIAL REJ. FOR:
9515	--	open	open	07	(CAT)
9517	--	70μA(R)	can't measure unstable	09	CAT
9528	--	shorted	shorted	09	CAT

INTERNAL VISUAL INSPECTION All three samples have separated between the internal wire lead and the die due to peeling of the die nickel plate layer. The silicone junction coatings are charred and cracked. S/N 9515 has a cracked die and 9517 die has a chip-out where the internal lead was formerly attached (see Figures B-1 through B-3).

CONCLUSIONS These samples were subjected to heat and power beyond their stress limits, which has caused fatal damage to their internal structures. The protective junction coating has been charred, leading to excess leakage. The die and internal lead attach metal has been melted and the "second nickel" plate used on the dice has peeled and separated with the connecting metal. All the dice are shorted (probably due to "thermal runaway") and two of them have cracks or chip-outs. The die fell out of S/N 9528 when touched. In summary, the samples failed due to excessive thermal and electrical stress.

*h_{FE} trace present. Cannot meet stated test conditions. (Leaky)
**h_{FE} trace very leaky.

D=drift H=hysteresis Inv=inversion R=resistive S=soft Uns=unstable

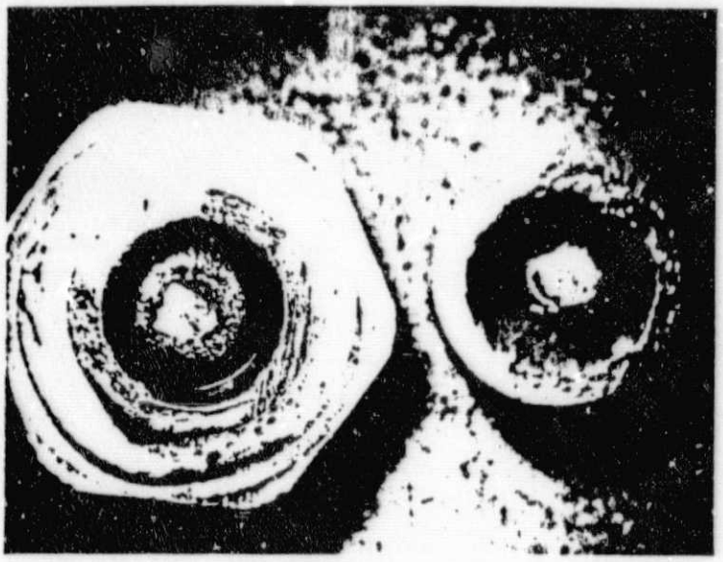


FIGURE B-1
S/N 9515, Lead Attachment Separation Due
to Peeling Nickel Plate, Siemens, 5X.
The silicone junction coating is charred and cracked.

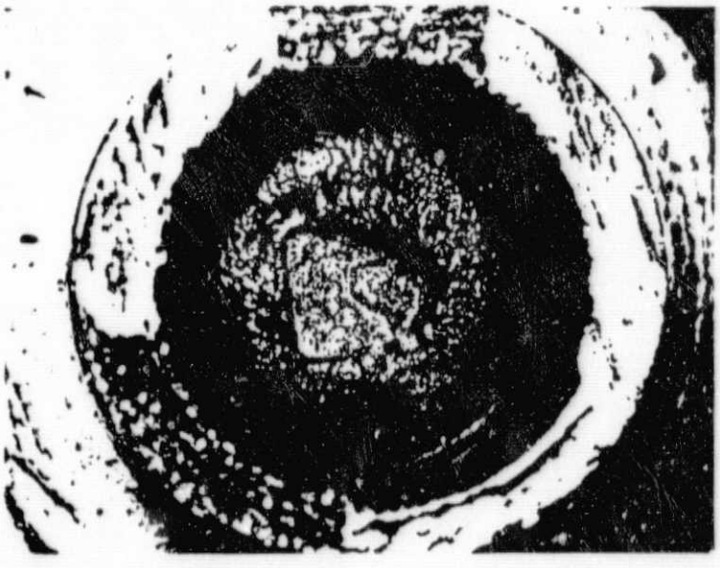


FIGURE B-2
S/N 9515, Siemens Die Surface, 10X.
Top die surface showing complete preparation
of the upper bonding layer, charring and cracking
of the junction coating. Note: Die is cracked.

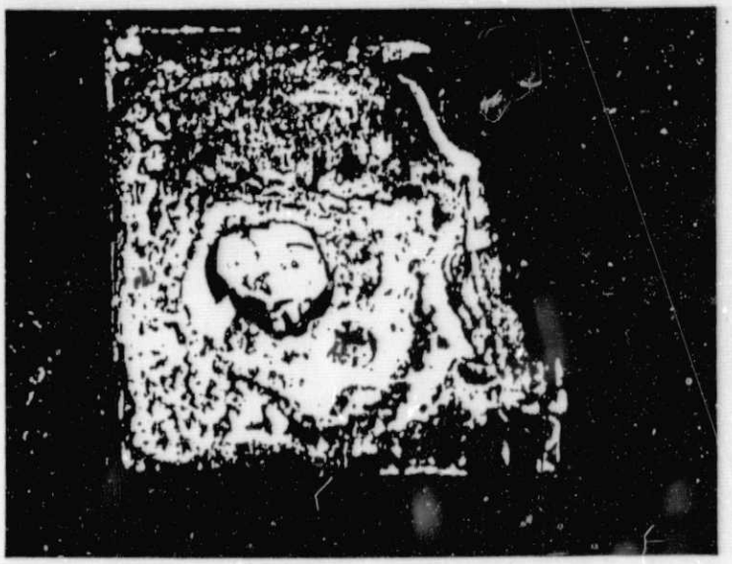


FIGURE B-3
S/N 9517, Pit in Top Die Surface and Complete
Loss of Bonding Layer, Siemens, 40X.